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THE GREAT WESTERN RALWAY.

(Continued from page 230.)

PERMANENT WAY.

The mode adopted in laying the rails is, I think, attempting to do that in a difficult and expensive manner, which may be done at least as well in a simple and more economical manner.

LOCOMOTIVE POWER.

Beyond what may have been said on this subject generally in the preceding parts of this Report, the length to which it has already extended forbids my saying much more. Generally, I should say, that the power of your engines should be proportioned to your loads.

Employing engines capable of drawing 200 tons to drag loads averaging 50 tons, will be very much like fastening eight horses to a post-chaise.

The great weight of locomotives is a positive evil. It is so, because they have to be carried about for nothing. It is so, because they do more harm to the road than any thing else, and a railway has to be made stronger and more costly on account of them. But to a certain extent, it is a necessary evil, but only to a certain extent. And if the weight be increased beyond this limit, it will be so much thrown away.

The weight of the engine should be determined by the average load to be taken, and the nature of the gradients.

Moreover, the engines will work economically, or otherwise, in proportion as their power approximates to their loads.

The average of your passenger trains cannot be expected to be greater or heavier than on the Grand Junction Railway. Supposing them to be the same, as to weight; from your flatter gradients, engines of little more than two-thirds the power of those on the Grand Junction, and, therefore, of considerably less weight, would be sufficient for you to travel at equal velocities. If you wish to travel at double the velocity, of course you must have more powerful engines; but it should not be forgotten, that you can only travel at double the velocity, by pretty nearly doubling the cost.

Finally, I should say of your line, that the country is favourable, and the gradients good; naturally so, or in so far as they are dependent on the undulations of the country.

Further, with such a traffic as you may expect, and such a country, your line holds out great inducements for the investment of capital.

But the advantages of country will be lost sight of and nullified, if, for

the sake of a system, the cost of the road be greatly increased; and even the good gradients will be rendered of non-effect as to economy, if the speed be greatly increased: for greater speed will entail greater cost, and will be tantamount to steep gradients.

And though the *same results* may perhaps be obtained on railways of better gradients, with more dead weight than on railways of bad gradients, yet this seems to be merely bringing down the good line to the standard of the bad.

I am, gentlemen, your very obedient servant,
(Signed) JOHN HAWKSHAW.

Manchester, 4th October, 1838.

REPORT OF I. K. BRUNEL, ESQ.

TO THE DIRECTORS OF THE GREAT WESTERN RAILWAY COMPANY.

Gentlemen,—In compliance with your request, I beg to submit to you the following observations upon the only Report which you have laid before me; that expected from Mr. Nicholas Wood not having yet arrived.

Knowing that I should be called upon to express an opinion upon the subject of these two Reports, and that the time allowed me would necessarily be very short, I had proposed to class, as far as possible, their contents under two heads,—viz., first, *facts*, including under this head the statement of actual results ascertained upon the Great Western or other lines, and general principles, or rules, laid down and assumed as axioms, whether of mechanics, mathematics, or of the practical working or economy of railways; and secondly, of the *arguments* founded upon these facts or axioms, including the inferences drawn from them and the opinions expressed.

I proposed, in the next place, to consider how far the former were applicable to the case, and, what is of great importance, how far they constituted *all* the facts that it was necessary to state for the purpose of arriving at a fair conclusion. I intended then to have discussed the correctness of the latter, and thus to have arrived, by a clear and satisfactory process, at the object I had in view, which was, to give my opinions and my views on the same subect as that of the Reports; to compare them with those of the writers; to show wherein I agreed with them and where I differed, together with the reasons and grounds for the differences between us.

This would, I think, have laid before you a business-like view of the case, and such as I should have wished to have submitted to you. I regret that the peculiar nature of the only Report as yet received puts it out of my power to pursue this course; for having carefully read it, I found, that by confining myself to the division or classification which I had proposed, I should have passed over in silence a very great portion of its contents, unless I formed a third division, including neither such facts or arguments as I have described, but consisting of general remarks and hypothetical cases, and even the opinions of others founded upon hypothetical cases. It is true, there are many remarks and comparisons made which are not applied directly to the Great Western Railway, nor are they in terms stated to be strictly revalent: neither are the cases hypothetically put afterwards proved to have any practical existence *or* made to throw light upon any of the existing circumstances of the railway; but being interwoven with a Report, specially made, upon the Great Western Railway, they are calculated, however inadvertently, to mislead, unless their irrelevancy is pointed out.

I regret very much the necessity of considering these portions of the Report, as it involves the tedious process of referring almost to each page, and of frequently entering into long explanations to remove a misapprehension, produced, perhaps, only by a single word; but no alternative is left to me. The utmost extent to which I can venture to depart from the line pursued by the Report which I have before me, will be to consider the subject, in the first place, in what appears to me the engineering and business-like view, and then, subsequently and separately, to consider the particular manner in which the writer has treated the question.

The Report, after a few preliminary remarks, is divided under the following heads, and they are considered in the order stated,—namely, the objects to be obtained, the construction of a railway, or what are very properly called, "the conditions of the question;" the comparative advantages of good gradients; the width of gauge; Maidenhead bridge; the construction of the permanent way; and the locomotive power. I shall now consider the subjects in the same order, and for the sake of perfect accuracy, refer to the pages and paragraphs of the printed copy before me. As the opinions expressed, and the conclusion arrived at, in this Report, are generally, if not wholly diametrically opposed to those which I am known to entertain, and which I am now quite prepared to support, it is but just to state at the outset, that I differ altogether from the general principles laid down, which appear to me to be unsound, and, indeed, to be incorrectly and insufficiently expressed; and I must say, that I consider the reasoning fallacious and defective, and that many of the calculations are incorrect or erroneous from the omission of quantities or conditions which must affect the results.

In the Report, (p. 3), the conditions of the question are stated to be, "that there is to be the fullest regard to the wants and convenience of the public, but also a constant regard to the prospects and expectations of the shareholders," in which I concur. But the observations which follow, I entirely dissent from, for which I will shortly state my reasons. It is said that the "profits of a railway are determined by the ratio of the proceeds to the cost; if the latter be greatly increased, it becomes almost imperative on the proprietary to increase the former, either by curtailing the accommodations or by increasing the charge to the public."

In noticing this paragraph, I wish to premise that I deprecate, as much as any one, all *useless* expenditures, every increase of the capital of any company not justified by a fair probability of return, either by economy in the management of or in the maintenance of the work, or by increase in the income to be derived from traffic:—and I must distinctly say, that no departure from a sound and wise economy would ever receive my sanction. Having said this, I now, in answer to the observation I have quoted, would beg leave to remark, that at whatever cost a railway may have been constructed, the only way to increase its proceeds is the same in all cases: you can only induce the public to travel upon a railway by holding out better accommodation or lower charges, or both, than they can find elsewhere,—by, in fact, *reversing* the means recommended—by increasing the accommodation or curtailing the charges. Expedition, comfort, and cheapness, are the temptations to railroad travelling, and according to the degree in which they exist and are made manifest, will the public use the railway. The object is to get the largest income

by these means,—the income must depend upon the numbers carried,—the numbers carried, upon the facilities afforded. Let the railroad cost what it may, it by no such process as that recommended that "proceeds" can be increased, but by one just the reverse, which is and must be the common object of all companies,—viz., to obtain the maximum of traffic and income; and no curtailing of the accommodation, no increase of charge to the public, can do this.

It is stated in the succeeding paragraph (p. 4), that "the cost at which a party can be conveyed will be as the interest on the capital expended, added to the cost of working the road;" *and inversely, as the number carried*, should have been added. But this important condition, which totally alters the arithmetical result of the cost of transport, is altogether omitted. Again, in what immediately follows it is said, that if "capital be increased without effecting any material reduction in the cost of working, the consequence will be, that to increase proceeds the rates must be raised." May not the number of passengers and the traffic be increased by such additional outlay, and thereby the proceeds also?

Such are the principles of railway economy which are laid down: I might perhaps avoid the necessity of further discussing them, by dropping them as suddenly and as completely as they are dropped after this last-quoted paragraph in the report, but as an impression is produced (although no direct inference is drawn), by their assertion, I will examine what I conceive to be the views of the writer on their intrinsic merits.

The theory of trade advanced in this part of the report may be stated thus: that the only mode of increasing the gross profits is to incease the profit upon such article by raising the price, or by reducing the original outlay. No doubt this is one method, if it can be effected; but I believe it would be difficult to point out any one great branch of trade which has thriven in this country by such a course. But, on the contrary, in every branch of manufacture, each year the necessary machinery and plant become more costly, the price of the articles manufactured is reduced, and the profits upon any given quantity diminished; but the gross profits are at the same time maintained and increased by the great increase of consumption consequent upon diminished prices or improved quality.

In railways, the same principle applies, and, if possible, in a still greater degree; yet in the report it is assumed throughout that the consumption, or in the case of railways, the number of passengers and the traffic is a *constant quantity*, which, on the one hand, is secured to the railway, whatever may be its comparative inconveniences or defects, and, on the other hand, cannot be increased by any additional accommodation, or by any other inducement held out to the public.

It is upon these views that all the arguments adduced in favour of reduction of first cost are founded in this report: in no single instance is any allusion made to the possibility of increasing the number of passengers by improving the means of conveyance. The great argument of all the promoters of railways, the striking results of experience in every railway—namely, the increased number of travellers consequent upon the increased facilities of conveyance, is totally lost sight of.

It is unnecessary to dwell any longer on this point, more particularly as I shall have occasion to refer to it hereafter; but it appears to me clear that no conclusion founded upon this reasoning can be safely relied upon.

The next question—namely, the effect or value of gradients, is one so susceptible of calculation, that it might be supposed to be a point upon

which no great difference of opinion could exist; and when the calculations are exactly made, and the simple results clearly stated, no difference will be found to exist.

In the comparison between gradients of 10 feet per mile and 4 feet per mile (p. 5), in which a diminution of resistance when ascending the latter, as compared with the former, of 17 per cent. is admitted, data are assumed different from those generally given by the best authorities on the subject, and conditions most essential to an accurate comparison are omitted. Ten lbs. per ton are assumed as the resistance on a level; eight lbs. have generally been taken as nearer the truth, and, upon a railway in good order, with carriages also in good order, may safely be taken ar the total resistance of a train. The effect of gravity in inclinations of 4 feet, and 10 feet will be 1.7 lbs., and 4.25 lbs, which, with the constant of 8 lbs., makes 9 7 lbs., and 12.25 lbs. per ton; this, or 100 to 126, gives the ratio of the resistance on the two gradients, being already 26 per cent., instead of 17. But if the maximum load that an engine can draw (of course at the regular speed of the trains) up the incline be taken, the weight of the engine and tender must be deducted, in either case, to obtain the effective load. In fast trains, such as those running on the Liverpool and Manchester line, the engine and tender will be about 30 per cent. of the gross weight, in the three cases cited by the writer at p. 8 & 9, the proportion is even greater, being two-fifths, or 40 per cent.; but I will admit even one-fourth to be the proportion, which would be allowing a fast passenger-train to weigh nett 60 tons, with an engine and tender, such as those of the Grand Junction, weighing 20 tons. From 100 and 126 is therefore to be deducted one quarter of 100, or 25, leaving 75 and 101, which are as 100 to 134, being *an excess of* 34 *per cent.* instead of 17 in the nett load which the same engine will be capable of drawing at the same velocity up the incline of 4 feet over that which it would draw on an incline of 10 feet; but the writer, after making the calculation, proceeds to sink all comparison by the simple assertion, that "an inclined plane" of 1 in 528 (10 feet per mile) all average loads "coulp be taken." Undoubtedly they can, but at a proportionate sacrifice of power or speed, which ought to have been added: without it the statement is incorrect, and with it I do not understand the object of the observation. The naked result of the above calculation is not altered by the omission, although certainly it may in consequence escape the recollection of the trader.

In the next paragraph the same thing is asserted in a different shape. It would have been desirable to have had explained what was meant by a "full average load." It appears to be assumed as a fixed or constant quantity for all railways, and quite independently of the gradients, or even of the power of the engines. I do not understand how any such fixed quantity can exist. Several of the present trains on the Grand Junction Railway require two engines; should they increase so as to require three, it will probably be necessary to divide them; the capabilities of the line, or of the engines, will then have influenced the load. In the cases of the three different railways before referred to as quoted in the Report, the average nett loads of the trains referred to are, 24 tons, 32 tons, and 40 tons, respectively; and the average load in once case is therefore nearly double that in another. One

Whatever may be the results on other railways, we know from experiment on the Great Western, that our best engines, which are considered

so unnecessarily powerful, have been barely sufficient to take the loads which, under certain arrangements of trains, we are obliged to carry, and that intermediate or half-hour trains become necessary. That many such inconvenient arrangements would have been required if the loads had practically been increased 34 per cent., with gradients of 10 feet per mile, I need not tell you who are familiar with the details of our traffic. I regret the necessity of devoting so much space to an attempt to render more clear that which appears to me to be self-evident,—namely, that a load of 134 tons cannot be carried at the same speed and with the same power as one of 100 tons, or, in other words, that the addition of a useless load of 10 or 15 tons to one of our ordinary trains would not be unimportant; but the paragraph I have referred to implies this, and there being no argument advanced in support of it which could be examined, it becomes the more necessary to take notice of it.

The particular argument of the gradients on the Great Western Railway and their effect upon the traffic are then gone into; and at the end of the paragraph p. 6, the advantage of 17 per cent., before alluded to, is reduced one half, or $8\frac{1}{2}$ per cent. How this is done I have not been able to perceive, as I find neither argument nor calculation to justify it. It is, truly, very fairly given, as *an opinion;* but as there are many figures and quantities given in the course of the preceding paragraph at the conclusion of the paragraphs, the word "therefore" would lead a cursory reader to suppose it proved by some preceding calculation or reasoning. As some allusion is made to supposed savings of the power in one direction which is expended in the other, and as $8\frac{1}{2}$ is half of 17, it is barely possible that it is arrived at by a system of averaging the power required in the two directions; but in the first place, no such average can be taken; the maximum power that is required in any one part of the line must be provided, and must be carried at all times, even if no power at all be required on other parts of the line; and secondly, if the expenditure of power is to be averaged, then the increase of gradients makes *no difference* in the average power, as the decrease of power in descending is said to be equal to the increase in ascending, and therefore balances it. The fact is, that there is no ground whatever for halving the 17 per cent. (which I have shewn to be 34 per cent.) *as a measure of the effective power of the same engines under the two circumstances,* and consequently none whatever for fixing it at $8\frac{1}{2}$ per cent.

After this the $8\frac{1}{2}$ per cent is reduced to 2.8 per cent., in so far as relates to the value, in money, of such reduction in locomotive power; and the assertion is made, preceded again by the word "therefore," that a company would do wrong to increase the original capital more than 2.8 per cent. to effect a saving of 2.8 per cent. in the annual expenditure. Can it possibly be mean that if the capital be a certain sum, say 1000*l.* and the annual expenditure 150*l.*, leaving 150*l.* of nett profit, that a company would do wrong to add $2\frac{1}{2}$ per cent., to their original outlay, unless this secures $2\frac{1}{2}$ per cent saving, or 3*l.* 15s. on the annual expenditgre, or 15 per cent. for the money? This is evidently a great mistake, arising from the total confusion of the capital with the annual expenses. as if they were the same sum, and the apparent accuracy and proof are produced only by the repetition of the same figures in the two cases, although, in fact there is no such identity. The way in which a man of business should proceed would be to capitualize the annual sum likely to be saved at some given rate of interest, which in his opinion would cover all risk, and leave a profit, perhaps, of 6, 8, or ten per cent., according to cir-

cumstances, but having no reference to the particular per centage which the annual expenditure might bear to the capital; and this amount a wise man would expend, not only to increase his future profits, but also to *secure permanent advantages to the concern.*

The calculations, erroneous as I think I have shewn them to be, do nevertheless make out a case in favour of good gradients. But upon turning to a statement given of actual results upon three railways, these very calculations are annihilated. These experiments, if they prove any thing, prove an actual advantage in favour of gradients, not of four feet per mile, nor of ten feet but of very steep gradients of thirty feet per mile. The naked result, gives a less expense of power on two lines, on one of which half the length consists of gradients above twenty-six feet per mile, and on the other, eight miles out of twenty consist of gradients upwards of thirty-four feet per mile, over a line the maximum gradient of which is four feet per mile. No explanation is given. The question here is not one of the comparative perfection of the lines, in other respects, or of the carriages, or of the probable effects of circumstances not mentioned: it is adduced expressly as a practical measure of the value of gradients, and is left, without comment or explanation, to produce its effect on the mind of the reader. As such it does appear to me, and I think must to any impartial man, that the proof is overmuch, and becomes valueless: that the result cannot be correct, and that there evidently must either be an error in the data, or there must be circumstances quite independent of the gradients which require separation, otherwise we ase driven to the conclusion, that *steep gradients are the best.*

I have nothing betore me but the results, and therefore I cannot pretend to discover all the sources of error; but I know that some of the data are such as must introduce error; for instance, the consumption of coke given as that of the Great Western Railway, includes all that had been used in raising and keeping up the steam in the engines, which, in the first working of a portion of a line, and while the arrangements are not matured, is necessarily great; it includes also the coke expended in ballasting trains and experimental trips.

In fact, during the four weeks ending September 13th, which are referred to by the writer, I find that there were generally seven engines in use, and of these, two were employed upon the line, (not on the passenger traffic), and one was kept with the steam up, as a spare engine. How can the results of consumption per ton per mile be correct with such sources of error?

I must beg, however, to keep your attention to the 34 per cent. at which I have arrived, as the advantage, in actual *effective power*, of a gradient of 4 feet over one of 10 feet.

The gradients must ultimately govern the power of your engines, their speed (at all events in one direction), the size of each of your trains, and consequently their number; and it must always be remembered, that their operation is a *permanent* one, which nothing can remove or even alter, and the effect of which nothing can diminish. On the contrary, I am prepared to show, that the value of low gradients will, in all probability, be much increased.

I have assumed 8 lbs. per ton as the resistance of a train, but as the greatest part of this resistance depends upon the workmanship, the form, and the mechanical construction of the carriages, and other causes, and may be reduced by various contrivances already known, it would be con-

trary to all experience to suppose that it will not be materially reduced when there is an object to be gained by its reduction.

In many experiments, with all the circumstances favourable, the resistance has been as low as 6 lbs.

In some made by Mr. Hawkshaw, on the Great Western Railway, the resistance of a train, consisting partly of trucks and partly of carriages, only gives 6.22 lbs.

It may therefore be assumed, that we have now within our reach improvements by which the resistance may be reduced to 6 lbs.

With this datum, and making the same calculations as before, we obtain 100 and 144 as the comparative loads which the same engine would take at the same speed up the two gradients of 4 feet and 10 feet per mile.

Such an increase in the capabilities of engines must be of immense importance in passenger traffic. But how undeniably important it must be, even according to the principle laid down in the Report, in the conveyance of goods; in this service the maximum power of the engine *is* brought in operation, and *does* constitute the limit; and if the engine in such case only forms one-eighth of the gross load, the proportion will still be as 100 to 135.5.

The advantage, large as it is, is a highly probable one, and I venture to predict it as a certain one; but, confining ourselves to the results which may be obtained with the existing rails and carriages, I will consider what is the practical working of an increased useful effort of 34 per cent. by the same engine, or an increased resistance of 26 per cent. with the same load. According to the view of the writer, in page 5, of there being a fixed standard or average power of engine which will be the same in either case, the former,—namely, 34 per cent. of increased effect, would be the correct mode of considering the comparison. I will assume, however, the latter, as being the least advantageous, and I will suppose the engines, although different in power, to be of the same weight. Now, the resistance in ascending and descending a plane of four feet per mile will be 100 and 66; with the 10 feet per mile, it will be 126 in ascending, and actually only 39 in descending.

In the case of the Great Western Railway, from London to Slough, Maidenhead, Reading, and to the point of departure to Oxford, the maximum rise is 4 feet. Had it been 10 feet, as I must infer would have been the recommendation of Mr. Hawkshaw, the resistance going and coming would have been 126 and 89. Now, of what avail would it have been, that in returning to town the resistance was small? No more passengers or carriages could be brought one way than must be conveyed the other, or, to apply one of Mr. Hawkshaw's own similes, the eight horses required to take the post-chaise out must return with it, though two might be enough. I quite agree with the opinion very strongly expressed in another part of the Report, that for the economical working of locomotive engines, their power should *be well proportioned* to the load they have to draw. It is remarked, apparently in allusion to one which we consider the best engine in our establishment, that to use an engine *capable* of drawing 200 tons, to drag loads averaging 50 tons, will be very like fastening eight horses to a post-chase. Although the remark savours of ridicule, I quite concur in it. It is a forcible description of the practical working of a line with gradients of 10 feet per mile, such a line as the imaginary one (A B) described in p. 5, of the Report.

Now, on this line (A B), the engines going in one direction would

have to exert a power of 126, and this at full speed, and in the other of 39, or as 200 to 62—a proportion not very different from the 200 to 50, which is mentioned only as something that would be very absurd.

Again, at another part of the Report (p. 30), it is stated, that engines of little more than two-thirds the power of those on the Grand Junction Railway, and therefore of *considerable less weight*, would be sufficient on our line *from our flatter gradients*. Such an admitted reduction of 25 per cent. in locomotive power seems to me no mean economy to be obtained by these gradients, the effects of which are treated so lightly at other times; but these contradictory results are the necessary consequences of an attempt to argue against the simple facts, that the inclination of the line increases the resistance, and that if a regular speed is to be maintained, you must have power in proportion to that resistance.

All the foregoing calculations upon gradients have been limited to two cases of 10 feet and 4 feet per mile. These are both unusually favourable, and their comparison therefore is not calculated to render the advantages so striking; but had the gradient of 4 feet per mile been compared with the more ordinary ones of 16 feet and 20 feet, the superiority would have told much more in the discussion of the general question of the value of good gradients. To supply this deficiency I subjoin a table of the comparative effects of the same engine, with the same consumption of fuel, and travelling at the same speed on the level, and on the four gradients of 4, 10, 16, and twenty feet per mile, with a resistance of 8 lbs. for friction, &c.; and for the sake of uniformity with the previous calculations, I take the same standard of 100 as the useful effect, or nett load, up the plane of 10 feet.

	Comparative Effective Power.	
Gradients.	Ascending.	Descending.
Level	170	170
4 feet per mile	134	226
10 feet per mile	100	400
16 feet per mile	77	1305
20 feet per mile	66;	the load once in motion would *run* of itself.

The discrepancy between these results and those given in the Report does not arise merely from different data being assumed, and upon which there might be a difference of opinion; but from errors in the treatment of the calculation of the latter. I subjoin a similar table, calculated upon the basis of 10 lb. per ton, being the total resistance on a level.

	Comparative Effective Power.	
Gradients	Ascending.	Descending.
Level	156	156
4 feet per mile	129	195
10 feet per mile	100	297
16 feet per mile	80	556
20 feet per mile	69	726

By these tables the great superiority of a line approaching to the level is made apparent; not only is the effective power of the engine in that direction of the line which limits the load much greater, but the average work of the engine is performed more economically by the greater regularity of the resistance. On an inclination of ten feet per mile, as I have before shewn, the engine, during half the time is barely performing a quarter of the work which it is capable. On gradients of 16 feet per mile, the engine during half the time is barely doing more than driving itself.

These are incontrovertible facts; whether the total resistance arises from friction, from the resistance of the atmosphere, or from whatever cause, the amount is about as stated, and the increase caused by the gradients is in the ratio stated in the above table.

It appears to me almost to weaken the strength and obscure the clearness of a demonstration which is mathematical in its correctness and certainty, to attempt to support it by reference to certain experiments in which other causes might have operated; but on the Great Western Railway we have every day, and with every train, such evident and striking proofs of the effect of gradients, that I should have thought it must be conclusive to any one who has had an opportunity of witnessing them.

With powerful engines and light trains, running at a good speed of 30 to 35 miles per hour, the changes of gradients (which only vary from a level to 2 feet per mile, and to 4 feet per mile,) are perfectly perceptible in the increased or diminished speed, even without the assistance of a watch, and have been frequently detected by persons previously unacquainted with the levels.

It must always be borne in mind that the resistance arising from the gradients is a *permanent* evil, which, once established by the completion of the works, cannot be remedied, and the probable future effects of this must therefore be seriously considered. In the course of a few years, as railway travelling becomes general throughout the country, and there are opportunities of reaching every part of England by different roads, the usual results of competition will follow; prices will gradually be lowered; the number of travellers will become immensely increased; and the gross profits and expenditure become proportionably large; bearing then, particularly the latter, a much greater ratio to the original outlay than at present. The profits will then depend mainly upon the economy of transport, and then any saving in the current expenses will be felt in a far greater degree.

I shall now consider the subject of the width of gauge. The question of the disadvantage of differing in point of gauge from other railways, and the consequent exclusion from communication with them, is the first. This is undoubtedly an inconvenience; it amounts to a prohibition to almost any railway running northwards from London, as they must all more or less depend for their supply upon other lines or districts where railways already exist, and with which they must hope to be connected. In such cases there is no alternative.

The Great Western Railway, however, broke ground in an entirely new district, in which railways are unknown. At present it commands this district, and has already sent forth branches which embrace nearly all that can belong to it; and it will be the fault of the Company if it does not effectually and permanently secure to itself the whole trade of this portion of England, with that of South Wales and the south of Ireland; not by a forced monopoly, which could never long resist the wants of the public, but by such attention to these wants as shall render any competition unnecessary and hopeless. Such is the position of the Great Western Railway. It could have no connexion with any other of the main lines, and the principal branches likely to be made were well considered, and almost formed part of the original plan; nor can these be dependent upon any other existing lines for the traffic which they will bring to the main trunk.

At the London extremity, from the moment the junction, as originally proposed, with the London and Birmingham Railway was obliged to be given up, there existed no possibility of a connexion with any other line. London will always be the terminus of those main lines now established,

and which approach it from distinct quarters, and the traffic of each will cease at this point; and, unless when two such lines unite to form a common entrance into the town, they will have no connexion with each other at this extremity.

The Great Western was therefore free to adopt its own dimensions; and none of the difficulties which would entirely prevent such a course in the north of England had any existence in the west; and consequently, all the general arguments advanced, and the comparisons made, on the supposition of such difficulties occurring—all excellent in case they did—are totally inapplicable to the particular case of the Great Western Railway, to which they have no reference whatever.

The reasons for adopting any increased width of gauge, and the particular dimension of seven feet, have been so frequently before you, that it is unnecessary for me now to repeat them. The principal positive objection urged against it in the report is the increased cost, while the mechanical advantages are doubted, but not disproved.

As regards the cost, I have repeatedly shewn that this amounts at the utmost to a slight increase in the quantity of earthwork, and that the bridges, tunnels, &c., are not necessarily affected. Mr. Hawkshaw seems to be of the same opinion, as at p. 11 he classes the "tunnels of 30 feet diameter" among "the non-essentials," as "not absolutely consequent on the increase of gauge;" and at p. 13 he clearly limits the increased expense of construction to the earthwork, land, and permanent way. There is some inconsistency in these remarks, when compared with the estimate in page 24, where the width of tunnels is considered a consequence of the wide gauge, and a saving is estimated of 20 per cent. "in the tunnelling yet to be done, by the narrower gauge requiring four feet less width."

I have only here to repeat, what is really capable of the clearest proof—viz., that the greater width of tunnels, proposed by me for special reasons, which I have explained on more than one occasion, has nothing whatever to do with the wide gauge, inasmuch as tunnels of the ordinary width could be adopted, and the saving pointed out would not, therefore, be necessarily the result of the return to a narrower gauge. But the arguments advanced at p. 13 in the report, to show the necessity of increasing the *earthwork* by four feet, are subsequently, without observation, applied to the tunnels. This error is occasioned by neglecting to give precise dimensions to quantities quite capable of it.

Arguments are founded upon the assumption that a certain width is necessary between the centre rails for repairs. This is true, but the width should be stated in feet and inches. On the Liverpool and Manchester, this space is four feet eight inches; and, even with stone blocks, this is found ample for all purposes of repair: indeed, it is the width which is so perfect in Mr. Hawkshaw's estimation. Four feet eight inches, with stone blocks, (which does not leave more than two feet eight inches between the blocks), are not equal to four feet with longitudinal wooden sleepers, which would leave from two feet nine inches to three feet between them. Suppose four feet, however, to be necessary, then, with a seven feet gauge, the distance from centre to centre of the two lines is eleven feet, which is the same as on the London and Birmingham, Grand Junction, and other lines, and which has been adopted to give a general increase of space. The width of tunnels, viaducts, &c., are *therefore not necessarily affected* by the seven-feet gauge. Neither do I understand how the cost of the permanent way can be sensibly increased. The weight of rail would be the same. The engines, in other respects similar, would be, at the utmost,

only a few hundred-weight heavier, consequent upon the increased length of axles and breadth of frames—the boilers, fire-box, wheels, cylinders, and working gear (about nine-tenths of the whole) remaining exactly the same; and even with our present heavy engines, the greatest weight upon one pair of wheels is not greater than upon the driving wheels of Mr. Bury's engines on the London and Birmingham Railway.

If the strength of the rails be not increased, the mere distance between them cannot affect the expense of construction beyond the cost of a few cube feet of ballast per yard forward, and about eight loads of timber to the mile in transoms. If 150*l.* per mile is allowed for these sources of expence, it is far more than enough. This, with the 200*l.* assumed by Mr. Hawshaw for the earthwork, and 50*l.* for one quarter of an acre of land, which he has not allowed for, makes 400*l.* per mile as the outside of the additional cost incurred in the first construction of the road on the seven-feet gauge. As to the consequent increased cost in the engines and increased expense of repairs, they are treated in so general a way that it is difficult, if not impossible, to meet what is said; but certainly, actual experience satisfies me that eventually there will be no material difference in the first cost. The opinion of Messrs. Robert Stephenson and Company, as quoted page 28, is, that it "will not be very considerable." The wear and tear, I am equally satisfied, will be diminished. I

The whole subject of the diminished resistance arising from the increased diameter of wheels, and the opinion of the Irish commissioners in favor of it, is then disposed of in a summary manner. It is assumed that the bearings of the axles must be increased in the same ratio as the diameter of the wheels, and that hence no advantage would be gained, in so far as the friction was concerned; but such is not intended to be the case.

It is asserted that the grinding of the flanges against the rails must be more felt with a large wheel than a small one. No reason is given for expecting such a result, nor why this resistance should not be, as one might naturally expect, inversely as the square root of the diameter, and therefore diminishing with an increased diameter. As in the case of the gradients, however, the whole is set aside by one experiment; this experiment (page 15, 16, 17,) gives nearly the same result for wheels of three and four feet diameter. This is not surprising, as the difference in diameter was too small to be detected by the very uncertain and unsatisfactory mode hitherto adopted for ascertaining the resistance. It appears to me, also, that they were not made under similar circumstances, or even on the same road, and the ratio of the bearings to the wheels seem to be *rather in favour of the small wheels*. The experiment, therefore, appears to be perfectly useless and unavailable, and the writer says that he does not think it conclusive. Nevertheless, these are the only experiments adduced, whilst the point is assumed to be proved.

The next inquiry made is on the question of safety. I certainly never thought of the danger of *upsetting* from the narrowness of base, as a stage-coach occasionally does; and therefore I need not occupy your time in discussing the manner in which this imaginary argument has been advanced and then demolished. But I must call your attention to the extraordinary and contradictory general assertion (page 17) that "if A be safe, there cannot be the smallest advantage in making B safer." This is a confussion of words. If safety commonly speaking, meant a total absence of the possibility of danger, then the statement is contradictory,

and is not even sense; for if B is made safer than A, A cannot be perfectly safe. But safety is a term, after all, only used comparatively, and then the statement assumes this extraordinary shape—that if A be tolerably good, it is useless to seek any thing better. Now, although no man I believe, ever supposed that ordinary railway carriages were much exposed to the danger of being upset, yet no man could witness, as I have had the opportunity of doing, numerous accidents on railways of both dimensions, without being struck with the great difference in the susceptibility of the engines and carriages to being thrown off the rails on the 4 feet 8 inch gauge and on the 7-feet gauge. The reason is obvious enough: the oscillation and the velocity of the angular motion, or, in other words, the jerk caused by any departure from level in the rails, or from any open joint or obstacle, or from collision, must be much greater when acting on a 4 feet 8 inch base than on a 7-feet base, and I have seen many accidents on the 4 feet 8 inch rail arising wholly from this cause, while on the 7-feet gauge I have seen the same causes operating to a greater extent without producing any serious results. I believe, also, that at high velocities much of the resistance from the friction of the flanges, as well as the strain upon the carriages and liability to accident, arise from the lateral motion, which is imparted to the carriage by angular motion, or rolling, and which must be lessened in the direct proportion as the base is extended. The great difference in the rolling motion of the engine chimneys, when running at high speeds upon the 7-feet gauge, as compared with the same effect on 4 feet 8 inches, was remarked at once by the engine drivers sent by several of the manufacturers to erect their engines, and is familiar to all now engaged on the line, although the rails themselves were at that time undeniably in a bad state. Safety, therefore, may, and indeed must, be increased by the width of gauge. As to the effects of the adoption of the wide gauge by the main trunks upon the branch lines likely to emanate from it, as I said before, these branches have all formed part of the general plan, and were considered originally; and therefore the assumption of the writer, that there is uncertainty or danger upon this point, is not correct. The Bristol and Exeter Railway, which is the extension of the Great Western to the south-west of England, is well fitted to this gauge. A great extent of it will be the most level line in England, and is nearly straight. On the Cheltenham Railway, for four-fifths of the length it is free from any objectionable curve; and on the remainder there will be no curves of so small a radius, even in proportion to the 7-feet gauge, as there are on the Grand Junction and many other lines. The objections taken, therefore, are not applicable; and it seems to me that none of the grounds on which the writer founds his somewhat startling advice to alter all that has been done, are tenable. In fact, they are none of them brought forward in a clear and tangible shape, except the debit and credit account in page 26.

I will begin with the last, or the credit account. The first item is the largest, and considering that it constitutes two-thirds of the whole, it is a very important one; yet there is no proof, there is not even one single reason given for supposing any such increase; the only reference to it that I can find is in the middle of p. 13, where these words occur:—"The permanent road will also cost more if of the larger dimensions than if of the smaller; for it avails nothing to compare a light rail on the larger gauge, with a heavier rail on the smaller gauge, such comparisons must be made when other things are the same, or they amount to nothing." The

assertion here made is unsuported by a single argument or proof. What is meant by the truism contained in the allusion to the light rail and heavy rail, I am unable to comprehend. I have quoted it lest it should have some reference to a wide and narrow gauge, which I may not perceive.

I have shown, I think clearly, that 150*l.* per mile instead of 1,000*l.* is the excess: this makes a reduction of 85,000*l.* in the assumed saving. The 400*l.* excess on the engine and tender I equally dispute; it is also unsupported by any thing except the letter from Messrs. Stephenson, and their opinion is even much qualified: their concluding remark is—"If the power or dimensions of the engine be kept the same, the additional expense consequent upon an increase of gauge will not be very considerable." In fact, the same engine in all its material parts, and the same quantity of workmanship, answers for the one as the other; to widen the frame and lengthen the axles is all that is required; and even making no allowance for any increased facilities in the construction, 100*l.* will amply cover this,—say 150*l.*, as the increased expense consequent upon the wide gauge. This, of course, has no reference to any peculiar construction of the engine, such as greater evaporating surface or larger driving wheels, which are not, in fact, consequences of the width of gauge, but have been adopted with a view to economy of fuel and wear and tear.

In the next item I should add 50*l.* per mile of land, although neither upon earthwork, and still less upon land, have we 60 miles upon which we can effect the saving. The tunnelling, as I have shewn by actual calculation of the measurement required, is not affected by the gauge. The account, therefore, stand thus:

£150 per mile on 100 miles of permanent way - - - -	£15,000
£150 less on 60 engines and tender - - - - - - - -	9,000
£250 per mile on 60 miles of earthwork and land - - -	15,000
Tunnelling—nothing.	
	£39,000

Instead of £156,000 as given in the Report.

I now proceed to consider the debit account, in which I find an important omission. The change recommended from the 7-feet gauge to the 4-feet 8-inch, is supposed to occupy a year and a half; during this time no advantage could be taken of the extension of the line to Twyford, in the neighbourhood of Reading, which, if the opinions expressed in this Report are to be adopted, must be laid down with the narrow gauge, and it therefore would be useless until one of the lines of the same gauge was open. By this delay at least a year would be lost.

But besides this loss, another would be experienced by the confinement of the traffic to a single line. I believe it would be found impracticable to carry on our trade on a single line; there can be no doubt that it would be materially diminished, which, together with the loss of twelve months traffic between London and Twyford, cannot fail to make a difference of upwards of 50,000*l.* The gross receipts upon the present line are about 80,000*l.* per annum; the extension of the line from 22½ to 32 miles, (thereby securing all the long traffic, which is now only partially obtained,) and the natural progressive increase of the traffic which would take place on the present line, cannot be estimated to produce less than 60,000*l.* more, or 140,000*l.* per annum. Supposing the expenses to be increased by 25,000*l.*, there remains, as increased nett profits, 35,000*l.*; to this add 15,000*l.*, as a very moderate allowance for the reduction, to which I have alluded in our receipts, unavoidably conse-

quent upon the working of only a single line, which would certainly not diminish our expenses.

The debit account, therefore, will now stand:—

Expenses of alteration and loss upon stock, as stated in Report (page 24) - - - - - -	£123,976
Loss of profits on the extension to Twyford - -	35,000
Ditto on the traffic to Maidenhead - - - -	15,000
	£173,976

Instead of £123,976.

And deducting the amount to be saved, 39,000*l.*, it shows a sacrifice of 134,976*l.* as the result of the proposed alteration. Even if the assumed increase of 400*l.*, on the engine were admitted, it would still leave 121,-976, as the balance clear loss, it should also be remembered, that after the conversion of the one line to Maidenhead from the broad to the narrow gauge, the other still remains to be altered. During the whole of this operation, let me repeat, the total traffic to Reading must travel on a single line, which, even admitting it to be possible, must necessarily cause a continued loss of traffic, with great additional inconvenience and expense, and serious risk of accident,—all so much in *addition* to the amount of sacrifice already calculated.

MAIDENHEAD BRIDGE.

On this head it is unnecessary to say more than the defective part of the work has been condemned by me, and the contractor called upon to replace it, which he is now engaged in doing.

PERMANENT WAY.

The question of the construction of the permanent way appears to have been thought a very unimportant one: three lines of the Report are devoted to it, and these consist of the expression, in rather strong language, of an opinion unfavourable to the mode in which the attempt has been made; but whether the writer approves of the ultimate object sought to be attained—of the plan of continuous support—or not, does not in any way appear. This is to be regretted, as the writer has lately had some experience on this particular point, and it was supposed might have been able to give some useful information upon it.

LOCOMOTIVES.

The question of locomotive power is treated also very concisely; nothing whatever is stated, under this particular head, of the engines of the Great Western Railway. A few general principles are laid down, in almost all of which I perfectly concur,—viz., the necessity of proportioning the power of the engines to the loads; the advantage of keeping down the weight; the circumstance that the weight of the engine will depend on the average load to be taken, and the nature of the gradients. The comparison between the locomotive power supposed to be necessary on the Great Western and on the Grand Junction lines, is a powerful argument in favour of good gradients. On the whole, these principles are precisely those on which I have founded my arguments in the course of these observations, and I think they fully bear out the views I have taken, but the concluding observations of the Report appear to me to be the most strikingly erroneous views that I have yet had occasion to call your attention to, and still arising from the same mistake—that of omitting all consideration of increased profits to be derived from increased

accommodation or improved conveyance—objects at which I have aimed.

In the last paragraph but one, after condemning, very properly, any great increase in the cost of a road for the sake of a system, it is asserted that "good gradients will be rendered of non-effect, as to economy, if the speed be greatly increased, for greater speed will entail greater cost, and be tantamount to steep gradients."

It seems to me, on the contrary, that the attainment of a greater speed at the same cost is economical, just as it is to make a better and more saleable article at the same price. And the next and last paragraph exposes still more strongly this fallacious principle, and may be taken as a fair sample of the theory of railway economy advanced in this Report. The words are—"And though the same results may perhaps be obtained on railways of better gradients, with more dead weights, than on railways of bad gradients, yet this seems to be merely bringing down the good line to the standard of the bad;"—that is to say, if "more dead weights," or greater loads, are carried with "the same results," or at the same cost, no advantage is gained; so that, if natural or artificial means enable you to carry greater loads, and, in fact, *perform more work*, or in other words, *carry on a greater trade with the same capital*, you are not to avail yourself of these advantages to extend your business, but merely to withdraw so much capital from a thriving concern. If the sole object were to reduce the out-goings to the lowest possible scale, without reference to the comparative receipts, such a maxim might be good. If the construction of the railway, and the maintenance and working of it, were compulsory tax levied on the proprietors for the use of the public, without benefit to them, then indeed the only advantage of good gradients would be the diminution of exertion and of expenditure of power. To the beast of burden a good road is certainly of little consequence, if he is proportionably laden; but his owner would be surprised at being told that he could gain nothing by being able to carry more goods, because his horse would be worked *as much*, and worn out *as soon*, as when he carried less.

I shall now make a few observations on the remarks and the hypothetical cases which I before referred to, and I think when I have called your attention to them, you will agree with me that they ought not to pass entirely unnoticed.

In p. 2 of the Report, the difference between the Great Western Railway and other railways is compared to the difference between a canal for barges and a canal for ships—a most exaggerated comparison, and one by no means diminished in effect by the qualification introduced by the words which follow, "though not to an equal degree." A ship-canal is a totally different thing from a barge-canal; it is most costly, and if considered as a mere channel for the conveyance of goods, is very ill adapted for the purpose. It is intended solely for the transport of the ships to some inland port. The only change introduced in the Great Western Railway is in the dimension of one of the parts, not for the purpose of carrying larger *individual cargoes*, but for the purpose of carrying the ordinary cargoes more advantageously. If a comparison be made with canals, it should be simply with the case of a canal which, being intended for quick service, or fly-boats, is made rather wider, to allow the boats more free passage through the water, and thereby diminish the resistance. The comparison apparently is thought to require some apology, as it is said *not* to be *extraordinary* "*should it appear* that the lo-

comotives have twice the power of those on other lines;" and "*should it be shown* to be a parallel case to build a ship of 200 tons burthen, when there is no probability of ever obtaining a cargo of half the weight." This certainly is tantamount to the statement in a subsequent part of the Report, that the engines have this excess of power, and that we have, in fact, provided for a traffic four times as extensive as we can hope to obtain; yet, after producing this impression, the subject is dropped, and no attempt made in any part of the Report to prove it.

In the next paragraph (pages 2 and 3) there is a remark that "it is one thing to design that which is pleasing in outline and grand in dimensions, and it is altogether another thing to design that which, under all the circumstances, shall best answer the end in view, one of those ends being a return for the capital invested."

I must deny altogether that such a distinction necessarily exists. To make that large, *for the sake of appearance*, which ought to be small, is, unquestionably, very different from studying the right size and adopting it; but I think that when a work is evidently well adapted to the object for which it is intended, it is generally satisfactory to the eye; and that then there is rarely any difficulty in making it "pleasing in outline;" the distinction exists only with those who, like a bad archi ect, commence by designing the exterior of a building, and then make the interior arrangements subservient.

At the end of p. 3, a case is put which is strictly applicable, and which is solved in a manner to assist the subsequent arguments; but the solution seems to me to have no other merit, certainly not that of correctness.

It is supposed (what is indeed the actual case) that it is desired "to give the greatest impetus to the trade, and the greatest advantage to the town of Bristol;" and the way to do this is said to be, as if incontrovertible, "to connect it with the metropolis by a road on which parties could be carried for the smallest sum, and at a velocity *not inferior* to that at which they can be carried in any other direction." This is the first time I ever heard that to win the race it was sufficient to be *not behind* your competitor. If such were the rule in trade, why was the Liverpool and Manchester Railway made? The means of communication were not merely *not inferior* to, but probably superior to any in England. Why were railways introduced at all, and the capital embarked in the general means of transit so enormously increased by the *addition* of totally new work? Stage coaches and canals left all towns exactly in the position which is here said to ensure *the greatest impetus to their trade.* Besides, are there no points of inferiority in the case of the port of Bristol which have to be compensated for, in consequence of the superior local advantage of other ports? Bristol has, for some reason or other, fallen far believed Liverpool. Will it be of no advantage to the trade of this port, and thereby to the revenue of the railway, that it should have superior facilities of communication with London? Whether Liverpool continues at eleven-hours' or is reduced to eight-hours' distance from London, it may be said by some to be still a day's journey, while Bristol will be brought within four hours or four and a half hours' distance; and if this is reduced to three hours, which is undoubtedly practicable, letters and orders may be transmitted and replied to during the business hours of the day; and precisely the same change introduced into the transactions of business that was effected by the Liverpool and Manchester railway, and a great increase in the trade of the place and in *the traffic of the railway* must necessarily follow.

This doctrine of the all-sufficiency of *a railway*, without reference to its quality, and the inutility of attempting to influence the amount of traffic by increasing the advantages, appears, under different forms, in other parts, and I shall not again refer to it, but shall proceed to another part of the Report.

The adoption of a different gauge is compared, at p. 12, to the construction of a canal "in a country of canals, with locks of such a character as would totally shut out the boats of all the canals that surrounded it." Now, in the first place, as I have shown, the west of England is not a country of railways; and, in the next place, there is no similarity in the mode of conducting the carrying department of a railway and canal. A barge, with its master and his family living on board, may go, and does occasionally go, without inconvenience, far out of the usual beat. Railway carriages and waggons must belong to the particular line on which they run; and, except in such cases as the Grand Junction and Birmingham Railways, which form, in fact, one line, although they happen to be made by two companies, it will never pay to trust them in the hands of others.

On the subject of the wide gauge, the opinions of Mr. Booth, of the Liverpool and Manchester Railway (which had been previously expressed in a letter to the Irish Commissioners), and of Mr. Smith, of the Leeds and Selby Railway, are quoted in favour of the 4 feet 8 inch gauge, and their answer in the negative, given apparently to the direct question whether they thought there was any *want of safety*, or danger of *overturning*, on their *own railways*. The case is purely hypothetical. I never heard of the danger of overturning being advanced as an objection to the narrow gauge, although I have seen such a thing happen; and whether the objection be real or imaginary is the question to be decided by such a reference? At any rate, the Directors of the Great Western Railway were quite competent to select the referees for its decision.

I have the pleasure of being personally acquainted with both these gentlemen, and entertain the greatest respect for them; but I should never have thought of asking them such a question. If before building the Great Western steamship, we had written to some of the highly respectable and talented gentlemen who command the New York liners, and asked them if they considered there was any danger or inconvenience in the use of sails, and whether they should prefer steam, I think we might have anticipated their answers.

I shall here close my observations with the expressions of my regret that the manner in which the important questions at issue have been treated in the Report, has of itself prevented the discussion leading to any very satisfactory or useful conclusion. It has been almost impossible to do more than to show that, whatever may be the state of the case, the views taken in the Report, and the arguments advanced, are incorrect, and prove nothing. Another opportunity will probably occur of entering more fully into the real merits of the question, and for that I shall be prepared.

I am, gentlemen, your obedient servant,

London, 13th December, 1838. (Signed) I. K. BRUNEL.

REPORT OF NICHOLAS WOOD, ESQ.

Killingworth, Dec. 10th, 1838.

To the Directors of the Great Western Railway.

GENTLEMEN,—Having in my introductory letter to you of the 5th of Oct. last, entered at considerable length into the mode in which I had

deemed it necessary to conduct the inquiry intrusted to me, of reporting on the Great Western Railway, and the experiments which I found it necessary to make, to arrive at a decisive conclusion; it will be unnecessary again to repeat them in this report, especially as I understand you have determined, that the letter should be printed and laid before the shareholders, at the same time that this is presented to them.

In the preliminary report, I pointed out the necessity of subjecting as many of the important branches of the inquiry to experiment as possible, and enumerated, so far as I then could, the particular part of the system which appeared to me capable of being so subjected to experiment. In the prosecution of these, as in all experiments of this nature and description, innumerable and unforeseen difficulties have been met with, and, although as I have stated previously, every assistance has been rendered by every person connected with your establishment, yet the numerous obstacles unavoidably met with on such occasions have been in this instance so formidable, that it has been deemed advisable, and indeed neescsary, to curtail the experiments as much as possible, and only to perform those which were absolutely necessary to elucidate the system in a practical point of view. Still a body of facts has been obtained, which although perhaps not sufficiently comprehensive to embrace every subject connected with the inquiry in a scientific point of view, yet are of such extent and value as to enable me to enter upon the important task with much greater confidence, and certainly upon infinitely more secure grounds, than if I had merely confined myself to a personal inspection of the several works involved in the inquiry. And I likewise trust that, independently of the utility of these experiments, for the purposes of this inquiry, that the time, labour, and expense of performing them will be amply repaid by the information elicited by them, as a foundation for future operations; and by the additional, and in some cases, new, most important, and unexpected light thrown upon the whole system, which is now shown to be yet far from being fully developed, and which could only have become known by such like investigations. And this mode of investigation of the system is peculiary applicable to the case upon which I am called to report, the plans of construction and working of your railway being to a certain extent new, or, at any rate, different from those of a great majority of other railways, and having been adopted to remedy supposed defects of the old system; any experiments, therefore, which would not only exhibit the capabilities of your plans, but elucidate and develope all the properties, defective or otherwise, of the old system, must be of the greatest importance, as bringing before you in a tangible and more prominent and conclusive shape, than mere opinion, all those defects or properties of that system which it has been your object to improve and modify.

These experiments have been unremittingly prosecuted since the date of my last report, with the exception of the suspension of a few days, occasioned by a most melancholy accident; still the late period at which they have been terminated, (only on the 6th instant) and the early day which you state it is necessary you should receive my report, leaves me much less time than is necessary to properly compile and disgest all the various and complicated results and information elicited in the course of this extensive inquiry. This will render it necessary that I should confine myself as much as possible, to applying the result of the experiments and of my inquiries to the determination of the questions submitted to me, in a practical point of view; and shall not, more than is absolutely necessary

for the proper elucidation of the subject, in that respect, enter upon or distract your attention, by any theoretical or speculative results arising out of these experiments.

I shall therefore have to omit the consideration of some very important theoretical, and in some respects, practically useful considerations arising out of these experiments, which though necessary in a scientific point of view to elucidate the system of railways generally, yet which being applicable alike to railways of the ordinary description,and of that adopted by you, does not necessarily force itself upon my notice at this time; and which could not be properly considered within the period allowed me for making out this report, even if it had been advisable that such investigations should have been attempted.

With these remarks, I shall at once proceed to consider, the important questions embraced in your request, and the objects which appeared to me to be involved in the inquiry, and shall in detail point out the mode which I have adopted of determining the questions submitted to me; and the conclusions which, in a practical point of view seem, so far as my judgment enables me to pronounce an opinion, to result from these experiments and inquiries.

Your instructions were, that I should undertake an examination of that portion of the Great Western Railway now completed, and investigate the result of the whole system which has been adopted; and my attention is particularly directed to these points which may be said to constitute the peculiar features of the Great Western line, as contrasted with those of other railways, including in such inquiries the construction and efficiency of the engines, as well as every matter connected with the locomotive department of the company.

The Great Western Railway differs from the ordinary railways, in the width of gauge adopted, in the construction of the rails employed in framing the road, and in the adoption of much larger driving wheels than ordinary in the locomotive engines.

The subjects for consideration are therefore comprised under the following heads of inquiry,—viz. the width of gauge, the mode of constructing the road, and the efficiency, power, &c. of locomotive engines.

The increased width of gauge might have been adopted, and engines of the same description as those used on other railways might have been used, and it does not necessarily imply that the adopting an increased width, should render necessary the particular mode of construction adopted by Mr. Brunel, except in one point of view in which Mr. Brunel has put,—viz:—"That the increased width of gauge was necessary for the accomplishment of a high rate of speed, and that he believes continuous timber bearings to be a most essential improvement where high speeds are to be obtained." Still, as the two questions are in some degree distinct, we shall in the first instance consider them separately, and shall afterwards consider them in their connection with each other, as advanced by Mr. Brunel; and as the elucidation of these two heads of inquiry, includes that of the power of the locomotive engines, we shall not in this place make their consideration a distinct question.

In order, therefore, to bring the subject clearly before you, I shall first of all point out the *objects*, so far as I can learn from the published documents of your body, and from the reports of Mr. Brunel ,which have been expected to be realized by these departures from the more general plan of constructing and working railways, I shall then state some of the most prominent objections which have been made against the system, after

which I shall give, in detail, the inquiries and experiments which appeared to me necessary, to ascertain how far these benefits have been, or appear likely to be realised, and to what weight the objections appear to be entitled. The result of these inquiries and experiments will be next considered, and, with these materials, in obedience to your instructions, the system of construction of the Great Western Railway will be contrasted with the most improved railways of the ordinary construction and width of gauge.

Width of Gauge.—The width between the rails of all the public railways in England, is four feet eight and a half inches, the width of the Great Western Railway is seven feet; the difference is therefore nearly one-half more or two feet three and a half inches. From the documents previously alluded to—from a careful perusal of Mr. Brunel's reports—and from personal communications with that gentleman, the following appear to have been the prominent advantages expected to be derived from the increased width of gauge, and which induced the adoption of the width of seven feet.

Attainment of a high rate of Speed.—On this point Mr. Brunel remarks, "with the capability of carrying the line upwards of fifty miles out of London, on almost a dead level, and without any objectionable curves, and having beyond this, and for the whole distance to Bristol, excellent gradients, it was thought that unusually high speed might easily be attained; and that the very large extent of passenger traffic, which such a line would certainly command, would ensure a return for any advantages which could be offered to the public, either in increased speed, or in increased accommodation." For Mr. Brunel remarks—"I shall not attempt to argue with those who consider any increase of speed unnecessary, the public will always prefer that conveyance which is the most perfect, and speed within reasonable limits is a material ingredient in perfection in travelling," and the attainment of high speed appeared to involve the question of the width of gauge.

Mr. Brunel also considers, "that it would not have been embracing all the benefits derivable from the favourable gradients of the Great Western Railway, unless a more extended gauge was adopted, for if carriages and engines of a certain weight have not been found inconvenient upon one railway, greater weights may be employed, and the same results obtained on a railway with better gradients; and to adopt a gauge of the same number of inches on the Great Western Railway, as on the Grand Junction Railway would, in fact, amount practically to the use of a different gauge on similar railways, for the gauge which is well adapted to the one, is not well adapted to the other."

Mechanical advantage of increasing the Diameter of the Wheels, without raising the Bodies of the Carriages.—This comprehends what is deemed by Mr. Brunel, the most important parts of the advantage of an enlarged width of gauge, viz., the reduction of friction by the increased diameter of the wheels, which at the same time by being enabled to place the body of the carriage within the wheels, the centre of gravity of the carriage is kept low, and greater stability and steadiness of motion is expected to be obtained. Four feet wheels have been put upon the carriages at present in use upon the line, but Mr. Brunel states "that he looks forward to the employment of wheels of a larger diameter; and that he has been influenced to a considerable extent, in recommending the increased width of gauge, by its capabilities of prospective improvements, which may take place in the system of railroads." He states "that

though there are some causes which in practice slightly influence the result, yet practically the resistance from friction will be diminished exactly in the same ratio that the diameter of the wheels is increased," and " considering that the gradient of four feet per mile, only presents a resistance of less than two lbs. per ton, and that the friction of the carriages on ordinary railways amount to eight or nine lbs. per ton, being 8-10ths of the entire resistance, any diminution of the friction operates with considerably more effect upon a road with favourable, than one with more unfavourable gradients; and he further says " I am not by any means, at present prepared, to recommend any particular size of wheels, or even any increase of the present dimensions. I believe they will be materially increased; but my great object would be in every possible way to render each part capable of improvement, and to remove appears an obstacle to any great progress in such a very important point as the diameter of the wheels, upon which the resistance which governs the cost of transport, and the speed that may be obtained, so materially depends."

Admits all sorts of Carriages, Stage-Coaches, &c. to be carried within the wheels.—Presuming that the adoption of wheels of a large diameter is found beneficial, to the extent expected by Mr. Brunel, it became necessary that the carriages to be conveyed should be placed upon platforms within the wheels, to keep them as low as possible, which could not be done with carriages on railways of the ordinary width, a wider gauge seemed therefore necessary for this purpose.

Increased facilities for the adoption of larger and more powerful Locomotive Engines, for the attainment of higher rate of speed. Much stress has not been laid upon this by Mr. Brunel, although it has been alleged that great difficulties exist and that considerable expense is incurred by being obliged to compress the machinery into so small a space; and consequently, that a greater width of gauge would enable the manufacturer to make a more perfect machine, and by having more space for the machinery, the expense of repairs would be lessened.

Increased stability to the Carriages, and consequently increased steadiness of motion, not from any danger to be apprehended. by the centre of gravity being higher in carriages of a less width; but that higher carriages are more liable to oscillate upon the railway, than carriages of a greater width and less height, and that a considerable part of the friction is occasioned by the oscillation of the carriages, throwing the flanches of the wheels against the rails.

These appear to be the more prominent advantages set forth by Mr. Brunel, as consequent upon the adoption of an increased width of gauge. I have taken the extracts from the report to the Bristol meeting, in preference to quoting from Mr. Brunel's communications to the directors, inasmuch as that report is before the shareholders; and also in that report of Mr. Brunel enters somewhat minutely into details on the subject, and gives in a more determined and explicit plan the substance of all his communications to the directors on the subject. It would have increased the bulk of this report unnecessarily to have given all Mr. Brunel's reasons for the adoption of the increased width set before in that document, and this is also unnecessary, as the report itself is before the shareholders and can be referred to. These representations and recommendations of the engineer, appear to have been the principal reasons which had induced the adoption of an increased width of railway, as

stated in your report to the shareholders, at the half-yearly meeting of the 25th of August, 1836.

The objections which have been advanced against the adoption of this departure from the ordinary width of railways, have been principally the following, viz:

The increased cost of forming the road track of the Railway, in consequence of a greater width of base required for the superstructure of the rails, and upper works. That the carriages were required to be larger and heavier. That the increased width of gauge caused additional friction in passing through the curves. That it entailed a greater expense of constructing the engines and carriage, increased liability to the breakage of axles, &c. That it prevented a junction of the Great Western with other railways; and above all, that there were no advantages gained commensurate with the increased expense, and inconvenience of such a departure and disconnection from railways of the ordinary width, and several other objections which have been urged by different persons against the system, which it is not necessary to enumerate.

Previously to entering upon the consideration of the presumed benefits and objections incidental to the width of gauge, it will be advisable to bring before you the second part of the system of Mr. Brunel, viz: *the mode of constructing the Railway*, and in doing so I shall pursue the same plan as in the case of the consideration of width of gauge; first of all to point the reasons which seem to have influenced Mr. Brunel in the recommendation of this particular plan, and the improvements over other plans which he anticipated from its adoption; I shall then briefly state some of the principal objections which have been urged against it; and lastly, detail and report to you the mode I have deemed advisable to investigate, and determine all these conflicting questions, and then give the conclusions, which appear to me to result from the enquiries and experiments I have made.

Construction of the Road.—It will not be necessary for me to enter into a detailed description of Mr. Brunel's plan of constructing the Great Western Railway, further than what is absolutely necessary to explain principles of construction, and in what respects it differs from that of other railroads.

The plan adopted by Mr. Brunel is that of a continuous bearing of timber with piles, upon which the iron rails that constitute the track of the wheels are placed.

The construction may be thus shortly described,—Longitudinal timbers of a scantling of from five to seven inches in depth, and twelve to fourteen inches in breadth, and about thirty feet long are placed along the whole line. Then these timbers are bolted to cross sleepers or transoms at intervals or every fifteen feet; double transoms each six inches broad and nine inches deep being placed at the joinings of each of the longitudinal timbers, and single transoms of the same scantling being placed midway between the joinings. These transoms stretch across, and are bolted to all the four lines of rails. Within the two lines of rails of each track piles of beech are driven from the upper surface of the railway into the solid ground, so as to retain a firm hold thereof, and the transoms are bolted to the heads of these piles.

Sketches Nos. 1 and 2, Note A, Appendix, show this plan of constructing the railway. A B C D, and E F G H, are the longitudinal timbers; *a b a' b',* the double transoms; *c d*, the single transoms; and 1 2 3 4 the piles. Upon the longitudinal timbers, as shown at *r s*, in Sketch No.

3, a piece of hard wood is laid upon which the rail rests, A B being the longitudinal timber, and *e f* the transom. No. 4, D, shows the section of the rails on a larger scale, which is fastened down to the timbers and hard wood by iron screws.

The principal construction is this, the longitudinal timbers and transoms being held firmly down by the piles, gravel, or sand, is beat or packed underneath the longitudinal timbers, for the purpose of obtaining a considerable vertical strain upon the timbers upwards, and consequently to effect a corresponding firmness of foundation of packing underneath them. Without piles, the longitudinal timbers could not be packed in this manner, as there would be nothing to resist the pressure of the packing except their own weight, and the piles were therefore introduced to hold down the longitudinal timbers, and to render it practicable to introduce a force of packing underneath.

This plan is pointed out very clearly by Mr. Brunel in his report to you on the 22d of January, 1838, and presented to the Shareholders at the half yearly meeting on the 27th of February, 1838, and which, as it contains the reasons for its adoption, I give below :—

"The peculiarity of the plan which has been adopted, consists principally of two points ; first, in the use of a light flat rail, secured to timber, and supported over its entire surface, instead of a deep heavy rail supported only at intervals, and depending only on its own rigidity. Secondly, in the timbers which form the support of this rail being secured and held down to the ground, so that the hardness and degrees of resistance of the surface, upon which the timber rests, may be increased by ramming to an almost unlimited extent.

"The first, namely, the simple application of the rails upon longitudinal timbers is not new ; indeed, as mentioned in a former report, I believe it is the oldest form of railway in England, but when lately revived and tried upon several different railways it has not, I think, succeeded as fully as was anticipated, and I believe this is very much owing 'to the want of some such means as that which I have adopted for obtaining a solid and equal resistance under every part of the timber, and a consistent close contact between the timber and the ground.' As I believe this to be entirely new, and to constitute an essential part of the plan,' I trust I shall be excused dwelling upon it for the purpose of fully explaining it.

"In all the present systems of rail-laying, the supports, whether of stone blocks or wooden sleepers, simply rest upon the ground, and, consequently, only press upon the ground with a pressure due to their own weight; this is trifling compared either to the weight which rolls over them, or the stiffness of the rail which is secured to them. The block or sleeper must lie loosely upon the ground ; if you attempt to pack under it beyond a certain degree, you will only raise it, and for the same reason, it is impossible to pack under the whole surface of a block or sleeper ; one corner or end is unavoidably packed a little more than another, and from that moment the block or sleeper is hollow elsewhere. If this block yield as the weight rolls over, the rail itself resting on the two contiguous supports, is sufficiently stiff to raise it again, and the support becomes still more hollow ; such is the operation which may frequently be observed by the eye, more or less, in the best laid railways.

"Where contiguous longitudinal sleepers have been tried they have also been laid loose upon the ground ; having no weight themselves, their length has rendered it impossible that they should be well supported by

the ground underneath, or that they should continue so, even if it were practicable to lay them well in the first instance.

"It will be perceived at once that two lumps or two hard places in the round may leave such a timber unsupported for the interval of twenty or thirty feet in length, and, under the weight of an engine running rapidly over, it must in such a case yield and spring from the ground.

"In the present plan these timbers, which are much more substantial than those hitherto tried, are held down at short intervals of fifteen to eighteen feet, so they cannot be raised; gravel or sand is then rammed and beat under them, until at every point a solid resistance is created, more than sufficient to bear the greatest load that will come upon it; as the load rolls over, consequently the ground cannot yield; the timber which was held tight to the ground cannot yield, neither can it spring up as the weight leaves it; and the rail be securely fixed every where in close contact with the timber, that also is immoveable. Such was the theory of the plan, and the result of the experiment has fully confirmed my expectation of its success.

"The experiments have been made under several disadvantages, and I am glad that it has been so, as we are more likely to perceive at once, and to remedy any defects, which might otherwise have lain concealed for a time. The packing, upon which it is evident every thing depends, was effected during long continued wet, and while no drainage at all existed; looking forward to the necessity of repacking once or twice, the timbers and packing were left completely exposed. The severe frost which immediately followed converted the wet sand into a mass of stone, which we in vain attempted to disturb, and the continued dry frost has gradually evaporated the water it originally contained. The packing has shrunk considerably, and the exposed surfaces crumbled away, while the mass is still so hard within as to resist the pick-axe, and has been with some difficulty broken through at some points with a smith's cold chisel and hammer. Under these circumstances, with an engine weighing 14 or 15 tons, (and from want of adjustment, with more than half of this occasionally thrown upon one pair of wheels), constantly running over the rails, the timbers have stood most satisfactorily."

At the subsequent meeting (Oct. 10th, 1838), of the Great Western Railway Proprietors, Mr. Brunel thus gives his reason for the adoption of this plan of constructing the road.

"The mode of laying the rails is the next point which I shall consider. It may appear strange that I should again in this case disclaim having attempted anything perfectly new, yet regard to the truth compels me to do so. I have recommended in the case of the Great Western the principle of a continuous bearing of timber under the rail, instead of isolated supports, an old systém recently revived, and as such I described it in my report of January, 1338; the result of many hundred miles laid in this manner in America, and of some detached portions of railways in England, were quite sufficient to prove that the system was attended with many advantages, but since we first adopted it these proofs have been multiplied; there need now be no apprehension. There are railways in full work upon which the experiments has been tried sufficiently to prove beyond doubt, to those willing to be convinced, that a permanent way in continuous bearings of wood may be constructed, in which the motion will be much smoother, the noise less, and consequently—for they are effects produced by the same cause—the wear and tear of the machinery much less: such a plan is certainly best adapted for high speeds, and this

is the system recommended by me and adopted on our road. There are, no doubt, different modes of construction, and that which I have adopted as an improvement upon others, may, on the contrary, be attended with disadvantages. For the system, I will strenuously contend, but I should be sorry to enter with any such determined feeling into a discussion of the merits of the particular mode of construction. I would refer to my last report for the reasons which influenced me, and the objects I had in view in introducing the piling: that part which had been made under my own eye answered fully all my expectations."

These appear to have been the reasons for the introduction of this system of railway construction, and the objections raised against it have been —The increased cost of constructions beyond that of other modes,—the additional expense of keeping it in repair; and, that it does not accomplish the objects proposed by Mr. Brunel, in recommending it to your notice,—that the motion of the carriage is much greater than upon ordinary railways of the best construction,—and, that there is a considerable increase of resistance of the carriages.

The professed advantages to be derived from the increased width of gauge, and the construction of the road by continuous bearings and piles, are so extensive and numerous, while on the other hand, the objections alleged agaist them are equally so, that it appeared to me, as stated previously, with the exception of awaiting the result of the test of time, there was only one mode of determining these complicated questions with any degree of satisfaction,—viz.: to endeavour to investigate as many of the points as possible, by experiments instituted for the express purpose, and to ascertain, if by this mode such a number of facts could be obtained as would, with the aid of the experience already obtained of the working of the system, enable me to arrive at conclusions which would, to unprejudiced persons, determine the important questions submitted to me.

On a review of all the proposed advantages and above-enumerated objections, the most important points to be determined by experiment, appeared to me to be comprehended within the following heads of inquiry:—

1st. The question of the attainment of a higher rate of speed than on other railways; whether the increased width of gauge is, or is not, either necessary or best adapted for the accomplishment of this object, and to what extent.

2nd. The mechanical advantage or diminution of friction, by being enabled to increase the diameter of the wheels, without raising the bodies of the carriages; and in what respect, and to what extent, the friction or resistance of the carriages is effected by, or bears upon the peculiar construction of the road.

3rd. The comparative advantage or firmness of base, or road track of the Great Western Railway, with continuous timber bearings, either with or without piles, and if it does, or does not, produce a greater steadiness and smoothness of motion to the carriages, and to what extent.

These were the questions which appeared to me could not be determined in any other way than by experiment, but which appeared to be capable of solution by that method, and which likewise appeared to constitute the foundation of the entire system; for if the plan was not either necessary for the realization, or did not effect a greater rate of speed than ordinary railways;—if no diminution of friction was accomplished, and if no increased steadiness of motion to the carriages was produced, at least, a very considerable portion of the inducements for a departure

from the ordinary plan would be destroyed; but if, on the contrary, the whole or some part of these desiderata were accomplished, then it remained to be determined whether the advantages did, or did not, counterbalance the disadvantages, or objections to the system.

Attainment of Speed.—The first question to determine was, therefore, that of the attainment of speed. The most conclusive manner of effecting this appeared to be, to subject all the different descriptions of engines upon the line to experiment; to ascertain at what rate of speed they could travel, the loads they were capable of dragging at different rates of speed, and the comparative power required to accomplish these different performances. Having thus obtained the power of the Great Western Railway engines upon that railway, by instituting a similar set of experiments on other railways; we then had the comparative result of the engines as to speed, and performance upon the railways of the ordinary width and plan of construction, and upon the Great Western Railway.

A set of experiments for the purpose of ascertaining the performances of the several engines on the Great Western Railway was therefore commenced, and were conducted as follows:—

A certain number of first and second class carriages were selected and weighed; they were then loaded with such a weight as would equal that of their full complement of passengers, with their luggage. A certain number of trucks were also selected, weighed, and loaded with the weight which they were calculated to carry.

The engine selected for the experiment was weighed, and also the tender; the quantity of coke in the fire-grate of the engine was carefully observed at the commencement of the experiment, and also the quantity of water in the tender. The engine was then attached to the carriages fixed upon for the experiment, put in motion, and proceeded to the end of the stage without stopping. The coke having been previously weighed into bags, the quantity put into the fire-grate during the journey was recorded, and at the end of the trip the fire-grate was filled up, as nearly as could be estimated, to the same height above the fire grate as it was at the commencement of the trip, and the quantity thus consumed correctly ascertained. The quantity of water at the beginning of the trip being known, the boiler was kept to the same height during the journey, the quantity of water left in the tender at the end of the journey was gauged, and thus the quantity evaporated in the trip was obtained.

The mode of conducting the experiments was this:—Commencing at Paddington, the engine dragged the train from the depot to the first half-mile post, when it was stopped; the steam was then applied to the cylinders, and the time noted; for the first mile the time was recorded at every 110 yards, for the purpose of ascertaining the progress of obtaining the average speed, and afterwards at every quarter mile. The train then proceeded until it arrived at the twenty-first mile post, when the steam was shut off from the cylinders, and the train allowed to come to rest of itself. The quantity of coke consumed, and water evaporated, during each journey, was ascertained as previously explained; and the rate of speed being taken at every quarter mile, the rate of velocity was also obtained, not only during that part of the journey at which a maximum rate of speed was kept up, but also the time occupied in getting up the speed, and also of bringing the train to a state of rest. The same process was observed in the return trip from Maidenhead to Paddington; the engine, and train was brought up to the twenty-second mile post, and stopped, the

steam thrown upon the pistons, and the time, coke, and water ascertained in the same manner as in the former case.

Note B. Appendix, is a list of the names and dimensions of the engines subjected to experiment.

Note C, is a section of the gradients of the line, with the length and radius of the curve.

Note D, from No. 1 to No. 80, is an account of the experiments on the Great Western Railway, shewing the consumption of coke, water evaporated, and the time occupied in each trip with the different engines, with varying loads, and at different rates of speed.

Note E, from No. 1 to No. 3, is a summary of the experiments on the Great Western Railway, shewing the maximum and mean rate of speed attained in each experiment, the quantity of coke consumed and water evaporated during the trip, and also the quantity of coke consumed per ton per mile, both exclusive of, and including the engine and tender, also showing the powers of the several varieties of engines in use upon that railroad.

On attentively considering the result of these experiments, we find that the extreme mean maximum rate of speed accomplished by these engines, has been 41.15 miles an hour, with the North Star engine, but the load which was taken at that rate of speed was only 15 tons. It may here be observed, that the rate of speed shown in these tables is the mean rate from the time the engine obtained its full speed, until the steam was shut off at the end of the experiment, and comprehended a distance generally of 19 miles, as may be seen on inspecting the tables in note E, Appendix. A greater rate was accomplished for a short distance during some of the experiments, as much as 45 miles an hour.—The above expression of the maximum mean rate of speed is therefore the average rate of travelling from one end of the stage to the other, after the engine had got into full speed, and until the speed was again checked at the end of the stage.

A rate of 40½ miles an hour has, it will be seen, been accomplished by another engine, the Apollo, but with a load of only nine tons: when the load was increased, both with this engine and with the North Star, the speed was correspondingly reduced. The result of these experiments show that to effect a mean rate of about 40 miles an hour, exclusive of the time of getting up the speed and stopping at the termination, between the two ends of a stage, about twenty miles in length, the load cannot be more than from 15 to 20 tons, with engines of the power of the North Star.

It may be here remarked, that unless very large and heavy tenders are conveyed with the engines, the stages cannot be of a much longer distance than twenty miles; the quantity of water evaporated in this distance, by the North Star engine being upwards of three tons.

The performance with the North Star was with a six-wheel, and a four-wheel passenger carriage, capable of containing 56 passengers; the experiment with the Apollo engine was with a six-wheel carriage capable of containing 32 passengers, the full completment of luggage in both cases being allowed.

It is scarcely necessary to state, that this is a load which cannot be considered a profitable or advisable one, to be fixed upon as a standard for the weight of the trains; or such a load to be considered the weight of the trains on this Railroad for permanent adoption. It is only necessary to refer to the experiments, to see at what a sacrifice of power and

consumption of coke this rate of speed has been accomplished, to arrive at once at the conclusion, that if such a rate of speed cannot be kept up except at such a sacrifice, the rate must be reduced.

The Æolus engine with 24 tons, realised a rate of 37 miles an hour, and the twelve-inch cylinder engines with 18 tons, accomplished a similar performance; there are likewise loads below that which it will be necessary to provide for the regular traffic of the railway.

We come now to the next load, on which experiments were made, viz. 32 tons; this would provide accommodation for about 112 people with their luggage, with 2 six, and 2 four-wheel first-clases carriages; and with this load the North Star accomplished a rate of nearly 37 miles an hour, and the other engines about 34 miles. This is likewise a less load than can be reckoned upon for the permanent working of the line, as it does not allow for the conveyance of private carriages, which must always be calculated to accompany the swift or first-class trains.

With a load of 50 tons the speed realised by the Northern Star is nearly 35 miles an hour;—with the Æolus 32 miles;—but with the other engines only 26½ miles an hour.

When the load is increased to 80 tons, the North Star engine performs a rate of nearly 33 miles an hour; but the performance of the Æolus engine is diminished to 24¼ miles an hour; and we see that a rate of 22½ miles an hour is the performance of engines such as the Venus, Netptune, and Apollo, with 12 inch cylinders, and with 8 feet driving wheels; and with the Premier and Lion engines, with 14 inch cylinders, and 6 and 7 feet driving wheels respectively.

It does not appear, therefore, that with the best of engines at present upon the Great Western Railway, a greater velocity can be calculated upon; at the mean maximun rate of speed than 35 miles an hour, with such loads as may be expected to constitute a first-class train. For extraordinary purposes, with a diminished load, a rate of 40 miles may be attained, but looking at all the circumstances incidental to railways, with engines and trains travelling at the maximum rate of speed, it does not appear to me, that any standard equal to 40 miles an hour can be depended upon practice. The weight of two first-class carriages, one with six wheels, and one with four wheels, and of two second-class close-carriages, one with six wheels, and one with four wheels, with their complement of passengers and luggage, will weight about 31 tons; but this does not allow of any trucks for the conveyance of gentlemen's carriages, or for horse box. Upon the London and Birmingham Railway, since it has been opened throughout, the average weight of the trains, including passengers, passengers' carriages, carriage trucks, horse boxes and luggage vans, has been about 65 tons; this includes both first class and mixed trains, the former being upwards of 50 tons and the latter about 70 tons. Taking this as a standard for the Great Western Railway, it does not appear that, for the first-class trains a less weight than 50 tons can be calculated upon; and with this weight the experiments show that a mean rate of 35 miles an hour between the stages, after getting up the speed, and before its being checked may be accomplished, under circumstances similar to those experienced during the time these experiments were in being performed, and with engines of the power of the North Star. And it will be seen that with a load of 80 tons, which would not much exceed the weight of a second class train, a velocity of nearly 33 miles an hour can be maintained, during the time the engine is at the full rate of speed.

Taking 35 miles an hour therefore, as the mean maximum rate of speed

between the stages, it will have to be considered what general average rate can be kept up between one end of the line and the other; in this calculation we have to take into account, the time lost in getting up the speed, and in stopping the train, the time lost at each station, and all the vicissitudes of wind, weather, and incidental casualties. On the other hand, I think it my duty to explain, that these experiments, which are here brought forward as a standard for the assumption of this rate of speed on the Great Western Railway, though it is not expected that more weight should be placed upon them than upon experiments generally, which must be considered as exhibiting more favourable circumstances than the every day practical result; yet it must be taken into account, that the road for three or four miles from one end of the line was under repair, and would not therefore present what may be considered an average result, or what may be expected to be the permanent result when the road is in the best possible order. We shall see afterwards to what extent this may be supposed to influence the general results; I thought it my duty, however, to mention it in this place, that every circumstance connected with the inquiry likely to operate, in any degree whatever upon the general result, should be brought into consideration.

On a mere inspection of these Tables, every person must be struck with the enormous increase of power required to effect a high rate of speed, or a rate of 40 miles an hour, compared with that which is required to propel a load at the rate of about 20 miles an hour. We see the North Star engine, dragging 166 tons at the mean rate of 23¾ miles an hour; while the same engine under similar circumstances is only capable of dragging 15 tons at the rare of 41·15 miles an hour. Again the Æolus engine, drags 104 tons at the rate of nearly 23 miles an hour; and only 24 tons at the rate of 37·28 miles an hour. The engines of less power exhibit precisely the same results, we see them dragging 50 tons at 26½ miles an hour, and only nine tons at 40½ miles an hour.

If this had been the result of theoretical deduction, some suspicion might have existed of its accuracy, but the above is the result of carefully conducted experiments, made under precisely similar circumstances.

Mr. Verplanck's Report on the Revenue, Debt, and Financial Policy of the State of New-York.

The committee on Finance have had under consideration the several resolutions on which they were instructed to inquire and report to the Senate. The inquiries to which their attention was directed, involve the consideration of the whole financial condition and prosperity of the State, and of the cost, revenue and general policy of the great works of internal improvement, which are either actually in progress, or seem demanded by the wants or the will of the people. Instead therefore of answering singly to several points of the resolution in the precise order in which they are proposed, it is thought that the objects of the inquiry may be more satisfactorily obtained by a succinct exposition of the results of this examination, and of the views of finances and state policy which they suggest.

The first point of inquiry to which the attention is naturally directed is—

1. What is the probable cost of the great public works now actually in progress, and how much of this amount yet remains to be raised and expended?

These Works are,—*First*, and by far the most important, the Enlargement of the Erie Canal; *second*, the construction of the Genesee Valley Canal; *third*, the Black River Canal.

Whatever may have been the errors or the variations of former estimates of expense on these works, or the causes of such variation or errors, there seems to be every reason to rely upon the estimates last submitted by the Canal Commissioners, and the engineers in the service of the State, in answer to the inquiries of this committee, as well as more formally, in their recent reports to the Legislature. A large portion of the whole line of the Erie Canal is now actually under contract, amounting to about one half of the whole cost of the work, and embracing its most expensive and difficult parts. About ten per cent. of the whole estimated cost has been actually expended on various points and in different kinds of work. New surveys and measurements of the remaining parts having been made, with new estimates founded upon the prices of the actual payments and existing contracts, the results furnish materials for an estimate of the whole cost entitled to as full confidence as any estimate whatever can claim, and cannot, in all ordinary probability, be far from the truth.

The exyenditures, contracts and re-surveys of the Black River and Genesee Valley Canals, afford materials for a similar and equally satisfactory approximation to a precise estimate of the final cost of these works—more than four-fifths of the whole estimate of the Genesee Valley Canal, having been expended or contracted for, and more than half that of the Black River Canal.

The entire cost of the enlargement of the Erie Canal, as estimated by the Commissioners on these data, is	$23,402,800
The Genesee Valley Canal, if finished accoreing to its original plan, four-fifths of which are now under contract, will cost	4,900,000
The Black River Canal, (also including damages,) will cost	2,431,700
	$30,734,500
Of this amount there has already been expended up to the 1st of February, 1839—	
For the Erie enlargement,	$2,374,300
For the Genesee Valley,	436,500
For the Black River,	237,800
Amounting in all to	$3,048,600
Leaving to be expended,	$27,685,900
But of this amount there was provided from loans already made, and drawing interest in the banks until used, on February 1st, 1839,	$1,910,800
Leaving to be raised and applied for the construction of the canals on the plan and scale now under operation,	$25,760,100

Connected with the question of the probable amount of expense yet to be incurred for these works, is another presented by the resolution of inquiry—Whether or no any important economy can be obtained, consis-

tent with the successful future operation of the system, by altering and contracting the plan of the canals?

It has been stated by some, who have the best means of information, that economy and retrenchment in details may be effected to a considerable amount, and probably sufficient to balance any contingent increase of the aggregate expense from other unforeseen causes. But these relate to matters of detail, and do not touch the greater question of diminishing the scale of the enlarged Erie Canal—or of stoppiug that enlargnment, in its present dimensions, at Utica or Syracuse; and of retrenching the lateral canals in a similar manner.

It is not necessary here to enter into a yndiscussion of the policy of constructing the enlarged Erie Canal, on the ample scale adopted, and with very expensive, but durable and solid workmanship and materials. Some of the reasons for this are to be found in the reports of the Canal Commissioners. Whether these outweigh the additional expense, it would be the duty of the Legislature to inquire, if this were presented as an entirely new question. But whatever may have been the wisdom of that policy, (if it be doubtful,) it now seems neither wise nor easy to attempt economy by an essential alteration or contraction of the plan of the great canal.

In answer to the inquiries on this point by your committee, the acting Canal Commissioners replied, "that they are not aware of any advantageous change which can be made in the plan of the public works. They have added no specific reasons; but when it is considered, that above three millions had been already applied to the construction of these works on the present plan, on the first day of February last, and probably amounting to five millions paid or due before the first day of May—that about eleven millions worth of work on the Erie, and four and a half millions on the other canals, are already under contract, and in progress of execution or preparation of material—that the constructions already executed, or in progress, would be often either inconvenient or useless for a canal diminished in size in other parts,—it will be perceived, that now to contract or materially change the whole plan, would be to throw away much of what has already been expended, and would subject the State to very heavy damages upon the contracts already made, and in part acted upon —perhaps not less than twenty per cent. on the amount. The result then would be the obtaining an inferior, less useful, and less durable work, at very nearly the same cost with the completion of the present plan. It is probable that such a change could not be effected without a loss of five or six millions of dollars. Indeed, the loss might be nearly as great as any saving that could be effected by abandoning the present large dimensions and solid constructions, and substituting a smaller and cheaper work, which would certainly be always more expensive to the public in the cost of transportation, and less capable of meeting, in future years, the wants of the augmented population of the west,or of yielding to the State the increased revenue which the commerce of such a population would tender to our acceptance

If these views be appoved by the Legislature, there must be raised for the works in progress the sum of abou twenty-six millions, in such annual amounts as the means of the State, prudently administered and applied, may conveniently supply, and as the interests of commerce, as well as of the canal revenue, may hereafter require.

To be continued.